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Influence of Tillage Systems on Diversity and Abundance of Insect and Nematode Pests of Maize in Malete, Kwara State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author IAA is a Crop Protectionist (Entomologist) who designed the study, performed the statistical analysis, managed the literature searches, wrote the protocol, and wrote the first draft of the manuscript. Author OOL is a Geneticist who suggested and aided in the procurement of the ten quality protein maize varieties (QPMVs) from International Institute of Tropical Agriculture (IITA). Author AAW is a Soil physicist who suggested the tillage practices used in the experiment. Author KOA is a Soil Paedologist, provided the map of the study area. Author OSO was a Nematologist who provided the expertise for collection of nematode data. Author MMG aided in the collection of data and data analysis, managed the analyses of the study, managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Pests are major biotic factors causing up to 45% yield reduction in maize production. There is limited information on pests affecting maize in Malete, Kwara State, Nigeria. The types of insects and nematodes associated with ten quality protein maize varieties (QPMVs) were evaluated for pests' occurrence, abundance and diversity on 'plough only plots (POP)' and 'plough and harrow plots (PAHP)' as primary and secondary tillage, respectively.

The experiment was carried out using QPMVs at the Teaching and Research Farm of the Kwara State University, Malete and arranged in a randomised complete block design with 11 treatments

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replicated 3 times, including local check “pambo”. Data were collected on insect and nematode populations and yield parameters and analysed using ANOVA with descriptive statistics and standard diversity indices at $P\leq 0.05$.

A total of 833.1±4.0 and 799.3±3.4 arthropod individuals from POP and PAHP tillage practices, respectively comprising 8 orders and 18 families. *Ootheca mutabilis* was the most abundant species, with 5.47% (POP) and 5.68% (PAHP) and the least was *Rhopalosiphum maidis* 1.82% (POP) and 1.80% (PAHP). As indicated by Shannon-Wiener (3.46±0.023) and Simpson indices (0.97±0.0008), there was even distribution in the tillage practices. Three genera of plant parasitic nematodes (PPNs) namely: *Meloidogyne* spp. [(POP (78.33±19.65), PAHP (1.33±0.33)], *Pratylenchus* spp. [(POP (41.67±9.26), PAHP (5.00±2.31)], and *Helicotylenchus* spp. [(POP (58.33±38.35), PAHP (23.33±14.50)] were identified. The yield parameters and a number of the whole plant infested were significantly higher in the PAHP than the POP.

The use of secondary tillage practice is effective in reducing insects and nematodes associated with ten quality protein maize varieties and, therefore, recommended for the management of these pests in maize production.

Keywords: Quality protein maize; insect; nematodes; tillage practices and management.

1. INTRODUCTION

Maize (*Zea mays*) is a cereal crop that belongs to grass family *Poaceae*. It is a crop of global importance with significant adaptability in a wide range of climates and more diversely distributed than any other cereal crops [1]. It was introduced to West Africa by the Portuguese in the 16th century [2]. Maize is one of the most important grain crops in Nigeria, not only on the basis of the number of farmers that engaged in its cultivation but also in its economic value. Maize is a major fodder and grain crop being cultivated in the rainforest and the derived savannah zones of Nigeria [3] and has been in the diets of Nigerians for hundreds of years. The cultivation of maize in Nigeria began as a subsistence crop and has gradually become a more important crop. Maize has been upgraded to a commercial as many agro-based industries depending on it as raw materials [4]. Maize is a versatile crop as each part of the plant has economic value. Its grain, foliage, stalk, tassel and cob can all be used to produce large varieties of food and non-food products [5]. Its yield, among other grass families, is the most affected by variations in plant density due to its low tillering ability and the presence of a short-lived flowering period [6].

There are six major types of maize which include dent, flint, pod, popcorn, flour and sweet. Maize is an important source of carbohydrate and if eaten at the immature state, provides useful quantities of Vitamin A and C. Maize has varieties of different uses, its grains can be cooked, roasted, fried, ground, pounded or crushed to prepare local delicacies such as maize cake, pap, swallows and among others. These diets are prepared in different forms in various parts of Nigeria depending on the ethnic group (Yorubas or Hausas or Ibos) involved. In addition, maize is used as medicine and as raw materials for industries. In the study carried out by Abdulrahaman and Kolawole [7], about 28 food items and 6 medical values of maize were discussed. These food items include: hot and cold pap, ‘tuwo’, donkunnu’, ‘maasa’, ‘cous cous’, ‘Akple’,‘Ukejuka’, ‘Gwate’, ‘Nakia’, ‘Dambu alubosa’, ‘Abari’, ‘Egbo’, ‘Donkwa’, ‘Popcorn’, ‘Ajepasi’, ‘Aadun’, ‘Kokoro’, ‘Elekute’, and cooked and roasted maize.

Despite the importance of the crop, its production is constrained by a number of factors such as climatic factors, edaphic or soil factors, low yielding cultivars, birds, weeds, insect pests and diseases (caused by fungi, bacteria, viruses, and plant parasitic nematodes). More importantly, insects and nematodes cause serious yield and quality reduction in maize production. In different parts of the world, over 60 nematode species have been found associated with maize, and most of these have been recorded from roots, or soil around maize roots [8]. It is, therefore, essential to identify and estimate these pests to formulate appropriate management strategies. This project, therefore, aims at studying the diversity and damage assessment of insect and nematode pests of maize in Malete, Moro local Government, Kwara State, Nigeria. The objective of this study was to evaluate ten quality protein maize varieties for pest occurrence, abundance and diversity and to evaluate the influence of tillage practices in the management of these pests.

2. MATERIALS AND METHODS

The study to evaluate ten quality protein maize varieties (QPMVs) for pest's occurrence, abundance and diversity pests on different tillage practices ('plough only' and 'plough and harrow') was carried out during the 2015 rainy season at the Teaching and Research Farm of Kwara State University (KWASU), Malete (latitude 08^0 71'N; longitude $04^0$44'E) at 360 m above sea level [9]. KWASU is located in Malete, Moro Local Government Area of Kwara State, Nigeria (Fig. 1). The inhabitants of the community are engaged more in farming, hunting, transport, riding and trading. They cultivate arable crops such as cereals and legume crops. Maize is the most prominent cereal crop, while inhabitants grow the quite appreciable quantity of legumes especially cowpea. This experiment was conducted on Ferric Acrisol under rainfed conditions using POP and PAHP tillage practices. The QPMVs were evaluated for diurnal insect and nematode occurrence, abundance and diversity. The experiment was arranged in a randomised complete block design in four replicates on primary and secondary tillage plots. Data were collected on insect and nematode populations and yield parameters on each maize variety. Data collected were analysed using analysis of variance (ANOVA) with descriptive statistics. Paleontological Statistics 3.14 (PAST, 2016) software was used for measuring standard diversity indices such as Shannon Weiner index (H), Simpson diversity index (1-D) (Table 2) [10].

Table 1. Field parameters and measurements

Parameters	Measurements
Experimental Area	30 m×20 m
Experimental Block Dimension	22.5 m×10 m
Experimental Plot Dimension	7.5 m×10 m
Alley	0.5 m
Number of rows	11
Row length	10 m
Inter row spacing	0.75 m
Number of replicates	3
Inter plant spacing	0.25 m
Row width	10 m

Shannon index, the diversity of a community is similar to the amount of information in a code and it is calculated as $H' = -\sum p_i \ln p_i$, where pi is the proportion of individuals found in species i. In a sampled community, it can be estimated as $p_i = n_i/N$, where ni is the number of individuals in species i and N is the total number of individuals in the community. Since by definition the pis will all be between zero and one, the € natural log makes all of the terms of the summation negative, which is why we take the inverse of the sum. The values of H' are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase. The fact that the index incorporates both components of biodiversity can be seen as both strength and a weakness. It is a strength because it provides a simple, synthetic summary, but it is a weakness because it makes it difficult to compare communities that differ greatly in richness (Table 2) [10].

Simpson's index (D) is the most common dominance measure and since evenness and dominance are just two sides of a coin, i.e. their measures are complementary. Simpson's index is based on the probability of any two individuals drawn at random from an infinitely large community belonging to the same species. Therefore, Simpson's index is defined as $D = \sum p_i^2$. In a finite community, pi is the proportion of individuals found in species i. i.e. $D = \sum n_i (n_i - 1) / N (N - 1)$. However, since D is a measure of dominance, so as D increases, diversity decreases. Thus, Simpson's index is usually reported as its complement 1-D. Since D takes on values between zero and one and approaches one in the limit of a monoculture, (1-D) provides an intuitive proportional measure of diversity that is much less sensitive to species richness, where D is dominance (the most abundant insect species) and evenness (insect spread on the field) (E_H) at P=0.05 (Table 2) [10].

2.1 Experimental Plot and Its Management

The Germplasm used for planting was obtained from the International Institute for Tropical Agriculture (IITA) and Ilorin metropolis of Kwara State which were Quality Protein Maize varieties and "pambo" (local check), respectively. The ten quality protein maize varieties (QPMVs) obtained from IITA were: PVA SYN 11 F_2, PVA SYN 23 F_2, PVA SYN 15 F_2, PVA SYN 28 F_2, PVA SYN 15 F_2, PVA SYN 18 F_2, TZE QI 25, TZE QI 34, TZE QI 26, TZE QI 35. The site was mechanically cleared with a disc plough implement; the POP tillage plot was prepared by ploughing only, while the PAHP tillage was prepared by ploughing followed by harrowing. The debris was packed along the borders to control run-off. The land area, 30m×20 m, was laid out into two blocks of 20 m long each, with a spacing of 2.5 m between each block of 13.5-m-wide. Each block

Table 2. Summary of insect abundance and diversity associated with maize varieties in POP and PAHP tillage practices

Abundance/ Diversity indices	POP	PAHP	Remarks
Taxa_S	34.00 ± 0.00	34.00 ± 0.00	No. of Insect species in the study area
Individuals	870.00 ± 0.00	787.00 ± 0.00	Total number of insects in the study area
Dominance_D	0.03 ± 0.00	0.03 ± 0.00	No species dominate the ecosystem in both tillage practices
Simpson_1-D	0.97 ± 0.00	0.97 ± 0.00	Species are evenly distributed in the study area
Shannon_H	3.46 ± 0.02	3.45 ± 0.02	Species diversity is high in both tillage practices
Evenness_e^H/S	0.95 ± 0.02	0.92 ±0.02	Even distribution within each family in both tillage practices
Brillouin	3.32 ± 0.01	3.30 ± 0.02	Species diversity is high in both tillage practices
Menhinick	1.14 ± 0.00	1.20 ± 0.00	Species richness/plot is low
Margalef	4.88 ± 0.00	4.95 ± 0.00	Overall species richness is moderate
Equitability_J	0.98 ± 0.01	0.98 ± 0.01	Even distribution within each family in both tillage practices
Fisher_alpha	7.04 ± 0.01	7.23 ± 0.01	Species diversity is high in both tillage practices
Berger-Parker	0.06 ± 0.01	0.06 ± 0.01	No species dominate the ecosystem in both tillage practices
Chao-1	34.00 ± 0.00	34.00 ± 0.00	Number of insect species in the study area

contained three replicates each measuring 11m×5 m with 1.5 m spacing between replicates in each block (Table 1). The quality protein maize varieties and the pambo were assigned to the plots in randomized complete block design and replicated three times and a control. Seeds of each variety were sown by drilling with inter row spacing of 75 cm apart. Plants were later thinned to 20 stands per row at average intra spacing of 30 cm within each row at two weeks after sowing (WAS). Each plot contained 11 treatments replicated 10 times in a completely randomized block design (Table 1). The seeds were sown by drilling in mid-May with inter row spacing of 30 cm. Two seeds were sown per hole but later thinned to one plant stand per hole. Weeding was achieved by spraying with pre-emergence and post-emergence herbicides, Pendimenthalin and Glyphosphate, respectively, and subsequently weeded manually with hoe. The soil samples were randomly collected and analyzed. The deficiencies in the soil nutrient were augmented with NPK 15:15:15 fertiliser at the recommended rate of 400kg/ha at four weeks after planting. Watering and thinning were employed when necessary throughout the growing season.

2.2 Insect Diversity and Identification

The field survey for abundance and diversity of pests associated with maize aimed at identifying insects and nematodes affecting maize grown during the 2015 minor crop growing season in Malete, Kwara State, North central Nigeria. In this study, two methods of insects trapping were employed, namely: sweep net for flying insects and an improvised camel's hair brush for wingless and soil dwelling insects. The field trials were conducted to assess the abundance and diversity of insects associated with maize during the rainy season in July (which was later augmented by hand watering at when necessary). However, the abundance and diversity of insect and nematode populations associated with maize were estimated by improvised systematic (zig-zag) sampling (Fig. 2). The insect pests were randomly trapped in each replicate in the morning and evening between 06.00 and 6.30 hrs and 18.00 and 18.30 hrs [local time]. The number of insects' species per sample was taken at 14 days after sowing and, thereafter, fortnightly till harvesting by early August. The systematic samples were taken in four replicates. This was used to determine the frequency of occurrence of insect pests on *Zea mays* being evaluated during the wet season, which was in turn used in computing percentages occurrence of the insect pests. All samples collected were identified by comparing their morphological characteristics with insect paratypes on the Internet Insect Reference Collection Centre using taxonomic keys.

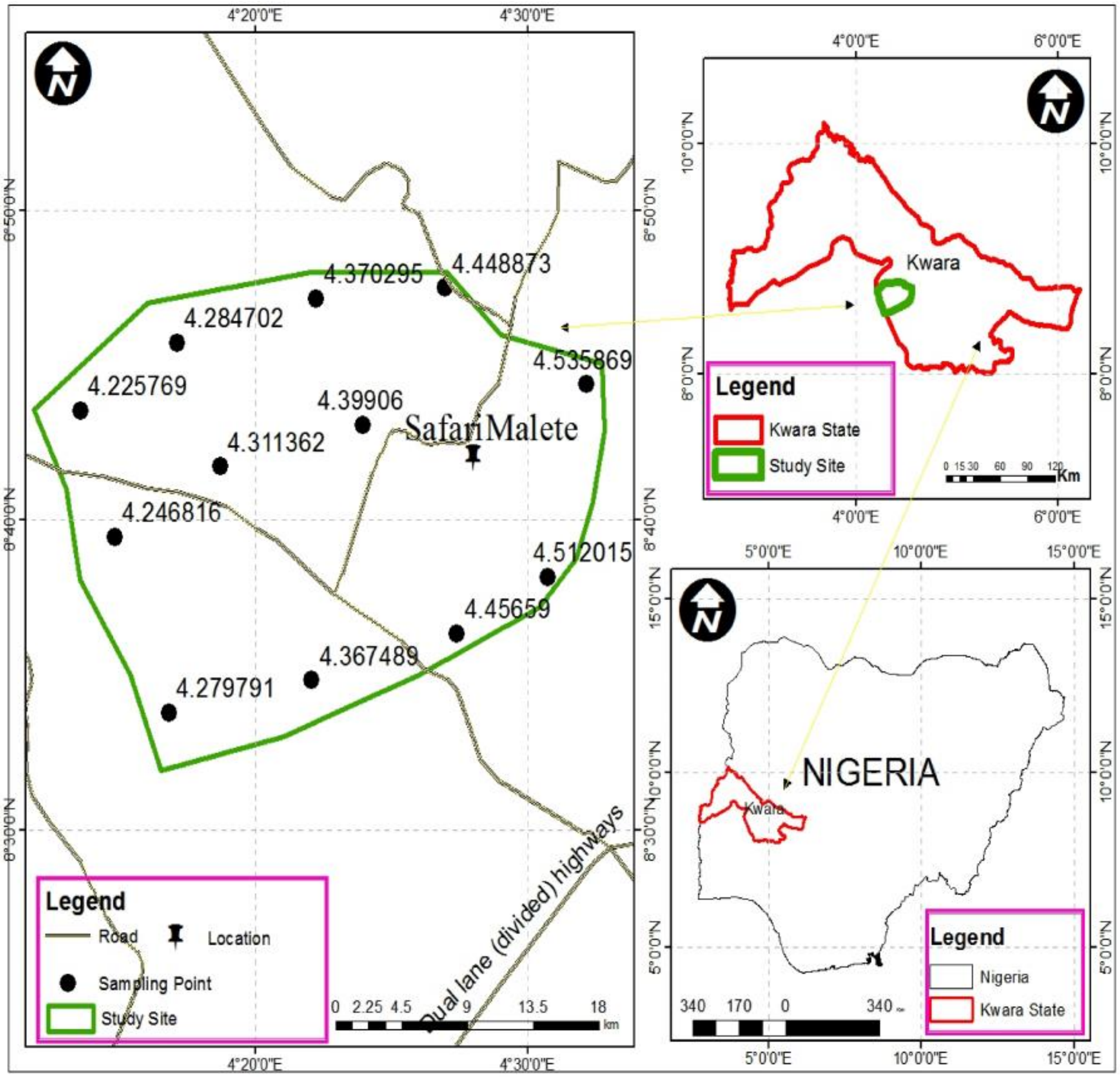

Fig. 1. Map of Malete (latitude 08^0 71'N; longitude $04^0$44'E at 360m above sea level), Moro Local Government Area of Kwara state, Nigeria

2.3 Extraction of Nematodes from Soil Samples

Plant-parasitic nematodes were extracted from soil samples collected from maize plots using tray method [11]. Here, active extraction methods based on the motion capacity of live nematodes was employed [12,13]. Two sieves separated by a double-ply facial tissue supported by two layers of nylon gauze which were placed on a collection tray and extracted for 48 hours and 500 ml of tap water was added and make up to standard. The second stage juveniles (J_2) were collected in beakers after 48 hours. For morphological study and identification, nematodes in each beaker were heat killed by adding an equal volume of boiling water to the nematode suspension in each beaker and each beaker were adjusted to 10 ml and later mounted on slides [14]. Each specimen was labelled appropriately and taken to International Institute of Tropical Agriculture (IITA) Nematology research laboratory, Ibadan, Oyo State for identification and quantification. Data collected were analysed using analysis of variance (ANOVA) with descriptive statistics.

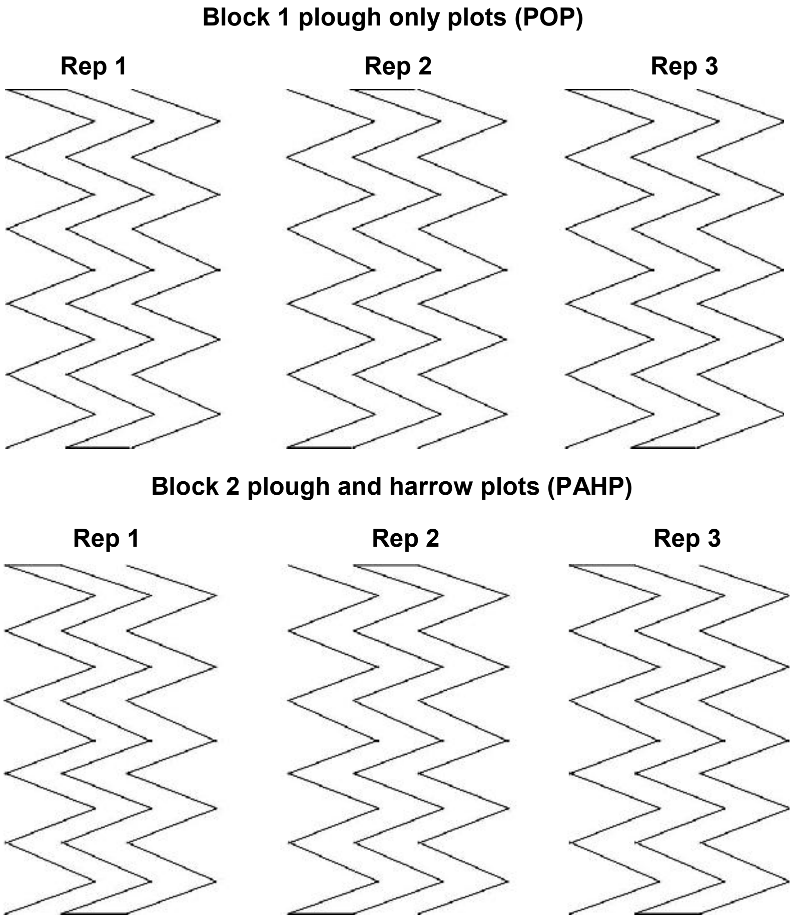

Fig. 2. Collection of soil samples in a systematic Zig-zag pattern in fields around selected maize plant stands

3. RESULTS

Abundance and diversity of diurnal insects associated with maize in KWASU teaching and Research (T & R) farm varied between the ploughed only plot (POP) and ploughed and harrowed plot (PAHP). A total of 883.1 ±4.0 individuals in POP and 799.3 ± 3.4 in PAHP (Table 3) comprising adults and immature stages of different insects from 17 families and 8 orders of insects were encountered during the field assessments. The six most abundant species in ploughed only plot were *Ootheca mutabilis* 48.3 ± 4.5(5.47%), *Locusta migratoria migratoroides* 43.1± 4.3 (4.88%), *Podagrica sjostedti* 34.9± 4.6 (3.95%), *Leucania convecta* 34.34 ± 4.8 (3.89%), *Diabrotica barberi* 33.1 ± 4.0 (3.75%), and *Zonocerus variegatus* 32.1± 4.1 (3.63`%), while in ploughed and harrowed plots, abundant species were *Ootheca mutabilis* 45.4 ±4.5(5.68%), *Locusta migratoria migratoroides* 39.7 ±4.5 (4.97%), *Podagrica sjostedti* 33.6 ±4.4 (4.20%), *Leucania convecta* 31.6 ±4.5 (3.95%), *Diabrotica barberi* 30.6 ±3.8 (3.83%) and *Zonocerus variegatus* 30.8 ±4.2 (3.85%). In PAHP, the populations of *Ootheca mutabilis* 45.4 ±4.5 and *Locusta migratoria migratoroides* 39.7 ±4.5 were not significantly (P>0.05) different from POP, and no significant (p≤0.05) differences were recorded in the population of *Podagrica sjostedti* 34.9± 4.6 (6.13%), *Leucania convecta* 34.34 ± 4.8, *Diabrotica barberi* 33.1 ± 4.0 (5.50%), and *Zonocerus variegatus* 32.1± 4.1 (3.99%) from that of POP. The most abundant species encountered during the study period was *Ootheca mutabilis* with a total of 48.3 ± 4.5 in POP and 45.4 ±4.5 in PAHP. This was followed by *L. migratoria migratoroides* with a total of 43.1± 4.3 in POP and 39.7 ±4.5 individuals in PAHP. The species were highly diversified with Simpson diversity index of 0.97±0.00 in POP and this was not significantly (p>0.05) different with species diversity recorded in PAHP. Similarly, the index of evenness was high being 0.95 ±

0.02 and 0.92 ± 0.02 for POP and PAHP, respectively as presented in Table 2. However, the defoliation inflicted by the insect species on maize plant was higher in POP (58.5%) than PAHP (41.5%) as shown in Table 4. On the whole plant stand, the number of leaves infested was higher in PAHP (64%) than in POP (35.6%) as shown in Table 5. From the soil samples collected from both tillage practices, three genera of plant parasitic nematodes (PPNs) namely: *Meloidogyne* spp. (POP = 78.33 ± 19.65, PAHP = 1.33 ± 0.33), *Pratylenchus* spp. (POP = 41.67 ± 9.26, PAHP = 5.00 ± 2.31), and *Helicotylenchus* spp. (POP = 58.33 ± 38.35, PAHP = 23.33 ± 14.50) were identified (Table 7). At the end of the experiment, maize cobs were harvested, shelled, dried to safe moisture (13.5^0C) and weighed. In POP, variety PVASYN11F_2 had the highest yield (2173.3 ± 792.1 kg/ha), while variety TZE QI20 recorded the highest yield (1729.3 ± 546.1 kg/ha) in PAHP (Table 6). The local variety 'PAMBO' recorded the least yield in both tillage practices (POP = 406.3 ± 12.2 kg/ha and PAHP = 908.0 ± 4.6 kg/ha) as shown in Table 6.

4. DISCUSSION

Pests are the most important factors limiting the quality and yields of maize production in Nigeria. In this study, *Ootheca mutabilis*, leaf eating beetle was the most devastating and abundant coleopteran pest, while *Locusta migratoria migratoroides* was the most abundant Orthoptera pest causing considerable damage by defoliating leaf of maize plant. This finding was previously described in detail by Aderolu et al. [15] who conducted similar studies on Amaranth. Also, Akinlosotu [16] found that *Hypolixus truncatulus* was the most abundant coleopteran pest causing considerable damage to amaranth.

The Shannon Weiner and Simpson indices of diversity revealed that there is no species dominance among the identified arthropods as the species were evenly distributed and highly diversified in both tillage practices under consideration implying the ease of using natural enemies and other eco-friendly methods in managing the identified pest species. This is in line with the findings of Aderolu et al. [15].

However, secondary tillage may enhance significantly higher physiological growth and yield performance. This is similar with an earlier report of Borin and Sartori [17] that among conventional tillage, minimum tillage and no-tillage in maize growing, the highest yield had been obtained with the conventional tillage. Maurya [18] also reported lower maize grain yield achieved with no-till system than with conventional tillage. Furthermore, conventional tillage improved the soil environment, resulted in increased maize yield [19] and reduced insect infestation. On the contrary, no-till farming may cause soil compaction and increase weed infestation [20] which could harbour insect pests. Secondary tillage could lead to improved soil structure and texture which supported easy percolation of water and air into the soil, thereby improving activities of soil organisms which transform organic matter into nutrients that were assimilated by maize plants [21]. The organic matters could also bind the soil particles into aggregates, maintain tilt, improve root penetration and minimise erosion [21].

Generally, maize plants infected with plant-parasitic nematodes are prone to root necrosis, galling and lesions (and other symptoms similar to that caused by fungal and bacterial infections) causing reduced quality and yield [22]. From the soil extraction in this study, three genera of plant parasitic nematodes were associated with maize plant including *Meloidogyne* spp, *Pratylenchus* spp. and *Helicotylenchus* spp. were identified. This findings are different from earlier reports by Fawole [23], Nicole et al. [24], who reported that between 11% -38% annual losses in production are caused by plant parasitic nematodes namely: lance nematode (*Hoplolaimus* spp.), root lesion nematode, (*Pratylenchus* spp.), root-knot-nematodes (*Meloidogyne* spp.), dagger nematode, (*Xiphenema* spp.), needle (*Longidorus* spp.), and spiral *(Scutellonema* spp.). Although, it partially agreed with the findings of Keetch, 1989 who stated that the most important groups of plant parasitic nematodes demonstrated to be significant limiting factors in maize production from all over the world include the root knot nematodes, *Meloidogyne* spp., the root lesion nematodes, *Pratylenchus* spp. and the cyst nematodes, *Heterodera* spp. Moreover, the intensity of soil cultivation and plant cover have been reported to impact the diversity and number of soil invertebrates more than fertilisers and herbicides [25]. Therefore, the variation in nematode genera could be due to soil variations in the experimental sites.

Table 3. Occurrence of insects associated with maize during wet season in Malete

S/N	**Species**	**Order**	**Family**	**POP**		**PAHP**	
				N=34		**N=34**	
1	*Chaetocnema pulicaria*	Coleoptera	Chrysomelidae	24.3	±3.6	21.2	±3.2
2	*Chaetocnema* hortensis	Coleoptera	Chrysomelidae	31.7	±3.9	30.4	±3.9
3	*Diabrotica barberi*	Coleoptera	Chrysomelidae	33.1	±4.0	30.6	±3.8
4	*Ootheca mutabilis*	Coleoptera	Chrysomelidae	48.3	±4.5	45.4	±4.5
5	*Podagrica sjostedti*	Coleoptera	Chrysomelidae	34.9	±4.6	33.6	±4.4
6	*Sphenophorus venatus*	Coleoptera	Curculionidae	24.2	±3.5	21.8	±3.4
7	*Naupactus leucoloma*	Coleoptera	Curculionidae	25.2	±3.5	23.3	±3.0
8	*Diatrea saccharalis*	Coleoptera	Crambidae	22.5	±3.2	20.1	±2.8
9	*Melanotus communis*	Coleoptera	Elateridae	24.5	±3.6	22.1	±3.1
10	*Coccinella magnifica*	Coleoptera	Meloidae	19.6	±3.6	15.1	±3.0
11	*Forficula auricularia*	Dermaptera	Forficulidae	19.7	±3.3	15.1	±2.8
12	*Atherigona orientalis*	Diptera	Muscidae	19.3	±3.5	16.6	±3.4
13	*Musca domestica*	Diptera	Muscidae	24.1	±16.9	19.0	±3.3
14	*Rhopalosiphum maidis*	Hemiptera	Aphididae	16.1	±2.7	14.4	±2.7
15	*Cicadulina mbila*	Hemiptera	Cicadellidae	21.3	±3.2	18.0	±3.2
16	*Cicadulina bimaculata*	Hemiptera	Cicadellidae	23.1	±3.2	18.0	±2.9
17	*Peregrinus maidis*	Hemiptera	Delphacidae	19.5	±3.1	18.4	±2.7
18	*Nezara viridula)*	Hemiptera	Pentatomidae	20.9	±3.1	18.4	±2.9
19	*Piezodorus hybneri*	Hemiptera	Pentatomidae	19.4	±3.4	18.0	±3.3
20	*Diatrea crambidoides*	Lepidoptera	Crambidae	27.1	±3.9	22.8	±3.7
21	*Busseola fusca*	Lepidoptera	Noctuidae	23.5	±4.3	22.2	±3.9
22	*Agrotis ipsilon*	Lepidoptera	Noctuidae	23.4	±3.1	21.1	±2.7
23	*Spodoptera frugiperda*	Lepidoptera	Noctuidae	23.4	±2.7	18.8	±2.6
24	*Mythimna separata*	Lepidoptera	Noctuidae	25.1	±3.7	23.1	±3.5
25	*Sesamia inferens*	Lepidoptera	Noctuidae	17.7	±2.7	17.3	±2.7
26	*Helicoverpea armigera*	Lepidoptera	Noctuidae	29.6	±3.9	28.6	±3.7
27	*Leucania convecta*	Lepidoptera	Noctuidae	34.3	±4.8	31.6	±4.5
28	*Elasmopalpus lignosellus*	Lepidoptera	Pyralidae	26.3	±4.6	24.1	±4.1
29	*Chilo partellus*	Lepidoptera	Pyralidae	27.1	±4.1	26.5	±4.0
30	*Spodoptera exempta*	Lepidoptera	Noctuidae	27.8	±3.4	27.1	±3.4
31	*L. migratoria migratoroides*	Orthoptera	Acrididae	43.1	±4.3	39.7	±4.5
32	*Zonocerus variegatus*	Orthoptera	Pyrgomophidae	32.1	±4.1	30.8	±4.2
33	*Frankliniella williamsi*	Thysanoptera	Thripidae	27.2	±3.2	25.6	±3.3
34	*Tetranychus urticae*	Trombidiformes	Tetranychidae	23.7	±3.1	20.5	±3.0
		Total		883.1	±4.0	799.3	±3.4

Table 4. The overall mean number of leaves infested with nematodes under POP and PAHP tillage practices

S/N	Trts	POP	PAHP
1	PVA SYN 11 F_2	65.0 ± 2.20	50.10 ± 9.60
2	PVA SYN 1 F_2	58.50 ± 8.40	45.60 ±7.00
3	PVA SYN 19 F_2	59.10 ± 13.10	45.10 ± 2.20
4	PVA SYN 10 F_2	56.30 ± 5.30	40.50 ± 1.20
5	PVA SYN 17 F_2	50.30 ± 6.10	33.10 ± 2.60
6	PVA SYN 9 $F_{2,}$	50.10 ± 5.10	39.30 ± 4.50
7	TZE QI 25	66.00 ± 13.70	45.30 ± 13.80
8	TZE QI 34	47.20 ± 6.70	32.60 ± 3.50
9	TZE QI 27	46.00 ± 2.40	41.00 ± 8.90
10	TZE QI 20	58.10 ± 9.50	32.00 ± 1.90
11	PAMBO	52.40 ± 7.80	27.50 ± 2.50

Keys: Trts = Treatments; POP = Plough only plot; PAPH= Ploughed and harrowed plot; PVA SYN= Pro Vitamin A Synthetic; TZE QI= Tropical Zea Quality

Table 5. The overall mean number of whole plant stand infested with nematodes in POP and PAHP tillage practices

S/N	Trts	POP	PAHP
1	PVA SYN 11 F_2	32.1 ± 5.1	59.0 ± 16.1
2	PVA SYN 1 F_2	18.0 ± 3.0	52.1 ± 9.3
3	PVA SYN 19 F_2	24.0 ± 7.5	54.1 ± 16.1
4	PVA SYN 10 F_2	25.1 ± 7.5	55.1 ± 21.1
5	PVA SYN 17 F_2	36.1 ± 7.5	52.0 ± 20.5
6	PVA SYN 9 $F_{2,}$	24.1 ± 4.2	43.1 ± 24.2
7	TZE QI 25	15.0 ± 7.3	33.1 ± 3.53
8	TZE QI 34	28.0 ± 5.0	52.0 ± 10.5
9	TZE QI 27	20.0 ± 8.2	42.4 ± 17.1
10	TZE QI 20	29.1 ± 9.0	38.5 ± 42.7
11	PAMBO	34.0 ± 2.3	34.8 ± 6.85

Keys: Trts = Treatments; POP = Plough only plot; PAPH= Ploughed and harrowed plot; PVA SYN= Pro Vitamin A Synthetic; TZE QI= Tropical Zea Quality

Table 6. The overall mean yield of Maize grain (kg/ha) obtained from plants affected with insect pests and nematodes varieties in POP and PAPH

S/N	TRTS	POP	PAPH
1	PVA SYN 11 F_2	1400.00 ± 264.60	1238.70 ± 197.50
2	PVA SYN 1 F_2	2173.30 ± 792.10	820.00 ± 205.10
3	PVA SYN 19 F_2	1133.30 ± 684.00	1020.00 ± 652.00
4	PVA SYN 10 F_2	1090.00 ± 559.90	986.70 ± 318.50
5	PVA SYN 17 F_2	1666.60 ± 712.60	894.70 ± 118.40
6	PVA SYN 9 $F_{2,}$	1166.70 ± 88.20	1320.00 ± 287.00
7	TZE QI 25	1133.30 ± 466.70	639.30 ± 11.60
8	TZE QI 34	1100.00 ± 400.00	1148.70 ± 396.20
9	TZE QI 27	1073.30 ± 549.10	1532.70 ±456.10
10	TZE QI 20	1433.30 ±409.60	1729.30 ±546.10
11	PAMBO	36.30 ± 12.20	908.00 ±4.60

Keys: Trts = Treatments; POP = Ploughed only plot; PAPH = Ploughed and harrowed Plot; PVA SYN= Pro Vitamin A Synthetic; TZE QI= Tropical Zea Quality

The pulverised soil in plough and harrow plot resulted in a reduction in nematode population when compared with plough only plot. This was probably due to exposure of nematodes in the secondary tillage practice to intense heat from sun rays. Hence, the outermost layer of the nematode cuticle is a thin, thermolabile, lipoid membrane [26] and could be easily destroyed by exposure.

Table 7. Estimation of identified plant parasitic nematode populations on maize varieties in POP and PAPH tillage plots

Nematode species	POP	PAPH
Meloidogyne spp.	78.33 ± 19.65	1.33 ± 0.33
Pratylenchus spp.	41.67 ± 9.26	5.00 ± 2.31
Helicotylenchus spp.	58.33 ± 38.35	23.33 ± 14.50

Keys: POP = Ploughed only plot; PAPH = Ploughed and harrowed tillage plot

5. CONCLUSION

The results of this study showed that ploughing followed by harrowing tillage practice significantly suppressed insect infestation and damage and improve growth rate and yield of maize varieties. There is no significant difference in insects' diversity in both PAHP and POP tillage practices. Hence, arthropod diversity in the maize field was, and field margins had a high diversity. However, insect and nematode populations were higher in POP than in PAHP thus implying suitability of PAHP for nematode management in maize production. Also, the quality protein maize variety (TZE QI 20) had better yield with minimal insect infestation and nematode infection under PAPH. Therefore, among other quality protein maize varieties, TZE QI 20 is recommended for breeding programme considering its nutritive attribute, lowest insect infestation, lower nematode infection and high yield potential compared with a local check, pambo.

6. RECOMMENDATION

Further research should be carried out to determine suitable eco-friendly control measure against insect, *Ootheca mutabilis*, thereby forming the basis for formulating control strategy in maize production. The severity of nematodes infection should also be carried out on maize in the study areas. Also, soil inhabiting arthropods which feed on nematodes should be investigated for use in IPM programme of plant parasitic nematodes associated with maize.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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